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99775-0800

FIRST-YEAR REPORT

AURORAL IMAGING FROM SPACELAB III

NASA GRANT NO. NAG5-635

November 1985

Principal Investigator: Thomas J. Hallinan
Co-Principal Investigator: Don Lind

(NASA-CR-178452) AURORAL IMAGING FROM SPACELAB 3 Yearly Report (Alaska Univ., Fairbanks.) 9 p HC A02/MF A01 CSCL 04A
N86-16792
Unclas
G3/46 05242

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The purpose of this grant was to acquire and analyze a comprehensive set of video and photographic images of the aurora from Spacelab III. Since each pass of Spacelab covers several hours of local time during an elapsed time of only a few minutes, it was hoped that these images would provide additional insight into the local-time dependence of the auroral morphology. Spacelab III was launched on April 29, 1985 and auroral data were obtained during the period April 30 to May 5.

This report discusses the preparations that were made for the auroral experiment, the quality and quantity of the data that were obtained, the initial scientific results, and ideas for further inquiry that were suggested by the preliminary review of the data.

Preparation - Although the auroral observations were relatively simple compared to most Spacelab experiments, considerable preparation was nonetheless required to assure a successful mission. Some of the specific preparations were as follows:

1) A training session was held in Fairbanks for astronauts Don Lind and Robert Overmeyer. This included actual observation and photography of the aurora, review of existing videotapes, discussion of the relevant science, and selection of scientific papers and popular articles about the aurora for background reading.

2) The 35 mm camera and lens were specified, based on the distance to the aurora, smearing due to orbital motion, etc.

3) Videotapes from the orbiter camera were reviewed to evaluate sensitivity.

4) The problem of optical contamination from the O_2 airglow was investigated. A suitable glass filter was selected to minimize this contamination with minimal attenuation of auroral light.

5) Numerous photographic films were tested on the aurora. Some of the films were also tested with different types of processing. On the basis of these tests, the 3-M, ISO 1000 color slide film was selected for the auroral photography and standard processing was recommended.

6) Arrangements were made to obtain the supporting data necessary for interpretation of the auroral images (time, location and attitude of orbiter, pan and tilt angles of the TV camera, voice comments).

7) Selection criteria for the auroral passes were established.

8) A video recorder was purchased that is compatible with the recorders at Johnson Space Center and is suitable for handling the data during the analysis phase.

9) The principal investigator participated in an investigators working group meeting and in a three-day simulation of the mission in Huntsville in October, 1984.

The mission and the initial assessment of the data - The principal investigator participated in the mission at the Payload Operations and Control Center at Johnson Space Center. Predictions of magnetic activity were obtained regularly from NOAA and were passed on to the crew. Occasional transmissions of the auroral video to the ground enabled the principal investigator to discuss procedures and observational strategies with crew-member (and Co-investigator) Don Lind who was running the video camera.

In general, the auroral observations went according to the initial plan. We obtained 274 color photographs of the aurora and approximately

5 hours of black-and-white video recordings. The data cover 22 separate passes from seven days. On several occasions, the Orbiter passed directly above the auroral forms.

The color photographs are of excellent quality (see Aviation Week, May 13, 1985; Sky and Telescope, July, 1985). Because of the schedule slippage, the mission occurred at full moon. The moonlit clouds were easily distinguished from aurora in the color images, but unfortunately they did contaminate the video data. Nonetheless, most of the video imagery is good and some of it is excellent.

One of the goals of the experiment was to test the technique of utilizing orbital motion to provide the parallax for hyper-stereoscopic views of the aurora. This worked quite well with both the 35 mm photography and with the video recordings. The 3-D images make it much easier to see the relationships between auroral forms. Moreover, in the video data the 3-D perspective allows us to more readily distinguish aurora from both atmospheric airglow and moonlit clouds.

One significant scientific result has already emerged from the photographic data. Horizontal layers of "enhanced aurora" (Hallinan et al., 1985) were, for the first time, observed from outside the earth's atmosphere. This eliminated any concern that the layers might be an optical illusion produced by atmospheric refraction. The layers are significant because their existence cannot be explained by simple collisional deposition of energy by precipitating electrons. Since the enhanced auroral layers (EA) were observed on 60-70% of the orbital passes, the data provide the first good information on the spatial and temporal distribution of this phenomenon.

The unique geometry afforded by the Spacelab III orbit also allowed the observation of EA in diffuse aurora--an observation that cannot be made from the ground. This is significant because the electron energy-distribution in the diffuse aurora is less likely to include "monoenergetic" peaks than is that of the discrete aurora. Hence it appears that the mechanism responsible for EA does not depend critically on the electron energy-distribution.

A second topic is the vertical extent of auroral rays as a function of local time. There appears to be a systematic dependence, with the tallest rays occurring well into the morning sector. This is in qualitative agreement with ground-based observations. But, for the first time, the opportunity exists to study the relationship quantitatively. This is important since the variability of vertical extents implies a related variability in the energy distribution of the electrons in the discrete aurora. A systematic local-time dependence might imply that the energy distribution is determined well out in the magnetosphere rather than in relatively local acceleration regions as is often assumed.

A third topic is the vertical extent of diffuse aurora--a measurement that cannot be made from the ground. The initial impression is that this extent is always small compared to that of the discrete aurora. This should be quantified and compared to expected values based on models of energy-deposition and on typical energy distributions for diffuse auroras.

The video data were compromised somewhat by scattered light from clouds illuminated by the full moon. Nonetheless, there appear to be sufficient data to examine the incidence of rapid ray motions as a function of local time. Since these ray motions are thought to be related to high-altitude perpendicular electric fields (Hallinan and Davis, 1970;

Carlqvist and Bostrom, 1970; Swift et al., 1976; Wagner et al., 1985), this gives some indication of the distribution of perpendicular electrostatic shocks. This should be compared with the available data from the S3-3 satellite.

The data include several clear examples of extended auroral forms that have well defined terminations to their horizontal lengths. A study of these "auroral ends" may well yield significant new insights into the physics of auroral arc formation.

Plans for continued analysis of the data - The data have all been logged along with preliminary descriptions. The next step is to complete a computer program to use the curved horizon and the visible stars to establish the locations and sizes of the auroral structures. (This will build on programs that we have already developed for the analysis of ground-based images of the aurora). A second computer program will locate the individual auroral features relative to magnetic time and the instantaneous auroral oval.

Once these analytical tools are in place, it will be relatively simple to relate the morphological characteristics and the size-scales (e.g., vertical extent) to the location in local time. We have requested copies of the April and May DMSP auroral images from the Southern Hemisphere. The comparison of these large-scale images with the somewhat more restricted but much more detailed images from Spacelab should prove useful. The 3-D images formed by sequential pairs of photographs from Spacelab III will also be very helpful in determining the spatial relationships between auroral forms.

Since the aurora depends on both local-time and substorm-time, it will also be necessary to obtain magnetometer data to locate the times of

substorm onsets. Thus each observed feature can be designated by latitude, local magnetic-time, and substorm-time.

Two major emphases in the data analysis will be the enhanced aurora (EA) and the vertical extent of diffuse aurora. These studies may well lead to fundamental shifts in our concepts of the mechanisms by which precipitating electrons deposit their kinetic energy in the atmosphere. In particular, it now appears that wave-particle interactions may be as important as individual collisions.

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